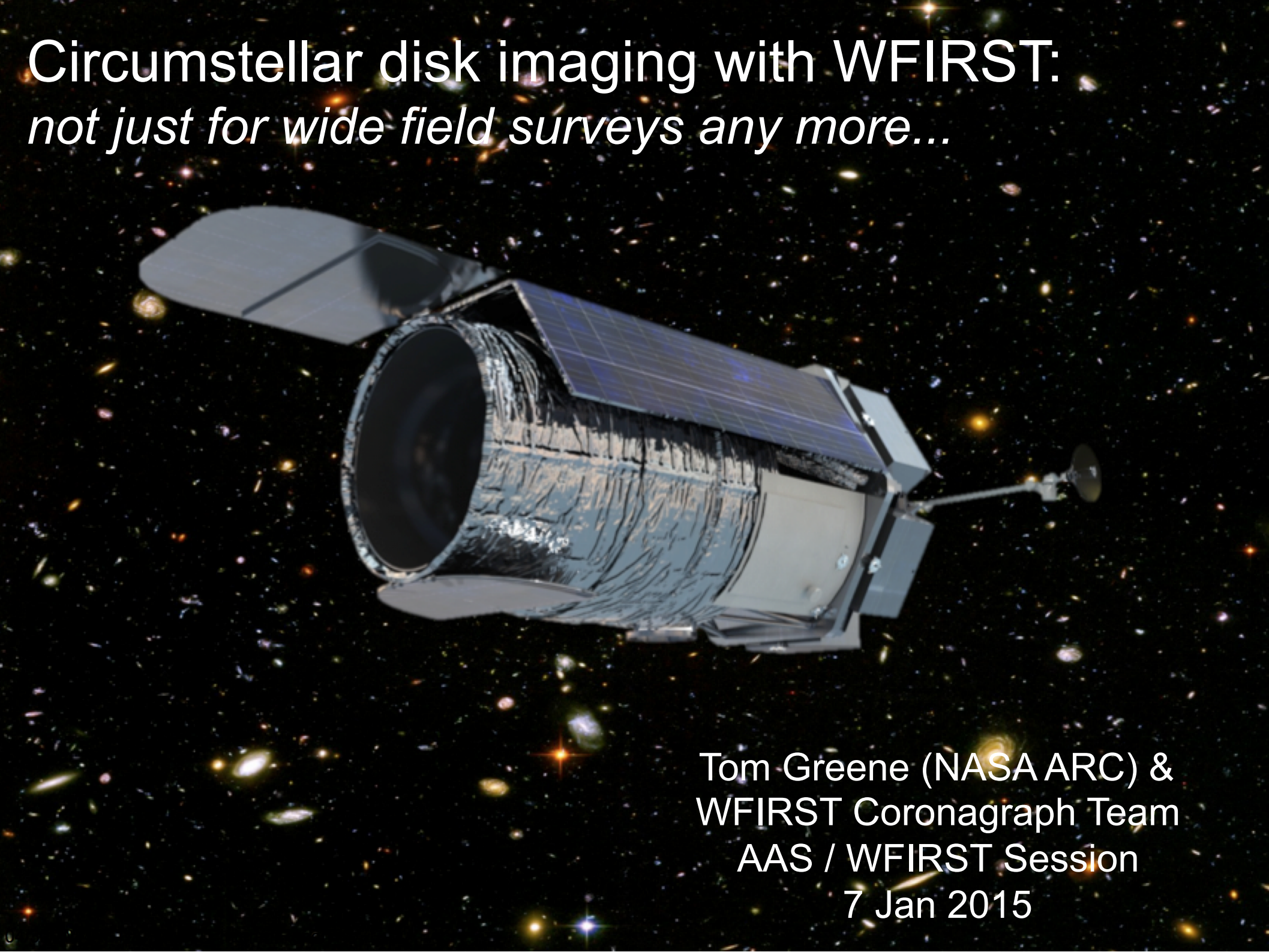
# Circumstellar disk imaging with WFIRST:
*not just for wide field surveys any more...*



Tom Greene (NASA ARC) &
WFIRST Coronagraph Team
AAS / WFIRST Session
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# WFIRST Coronagraph enables new disk science

***Extreme contrast (1E-9), small IWA, HST spatial resolution allow:***

A. Visible light studies of zodiacal disks around nearby stars (~10 pc)

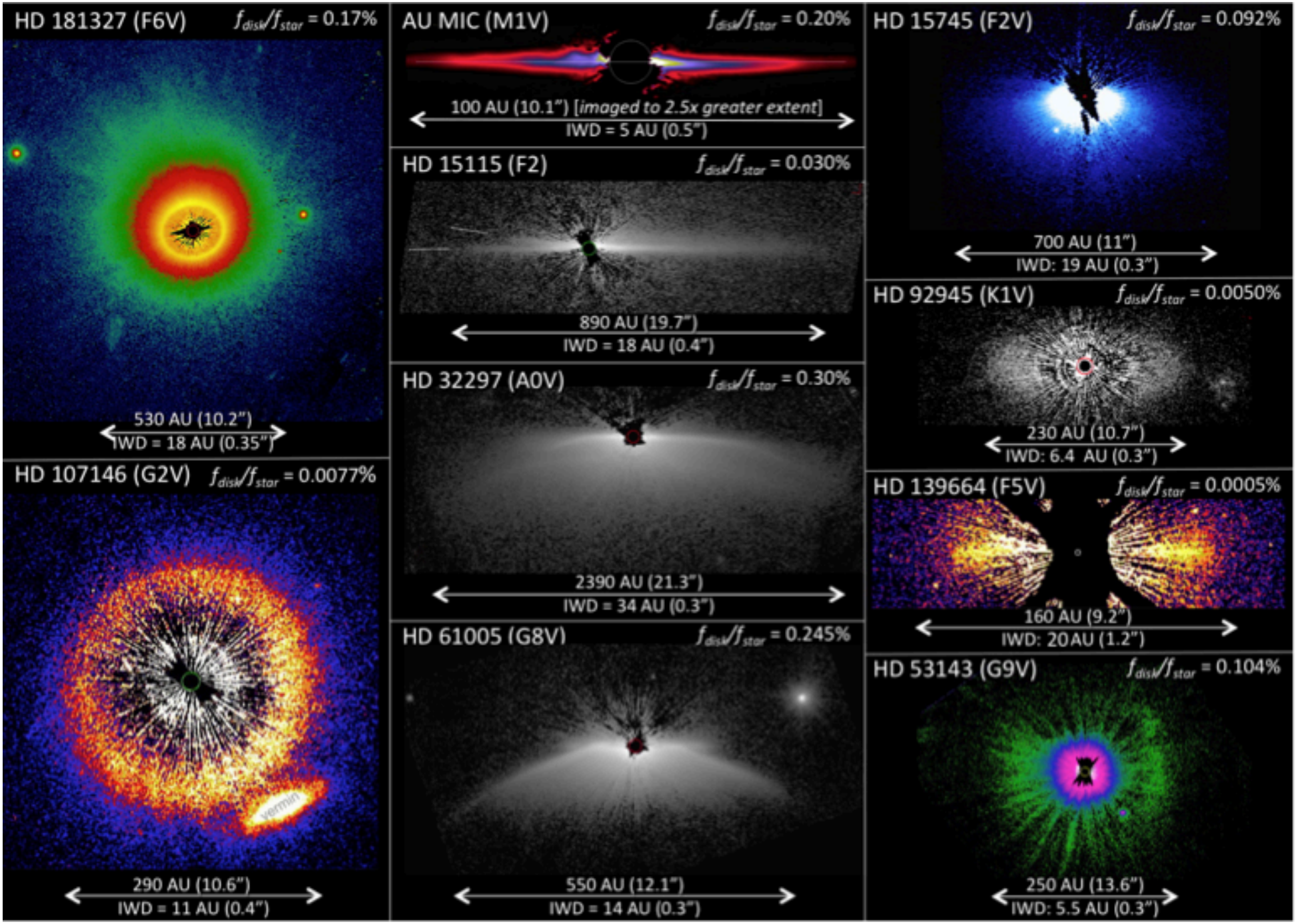
- Measure planet & dust content and collisional activity in planetary systems
- Diagnostic for future Earth-like planet imaging missions

B. Inner regions of young, large / massive debris disks resolved by HST, including systems with planets

- WFIRST-AFTA probes these disks much closer to stars than HST (~140 mas vs. 0.4” – 1.7”) at HST wavelengths and resolution w/ higher contrast
- Clear or dusty?; differences between systems with and without planets

C. Resolve the ~1 – 5 AU “asteroid belt" dust around many nearby stars detected by Spitzer and WISE in IR (> 50 zodi) and larger, cooler disks detected by Herschel.

# Debris Disks Today with HST (Schneider 2014)

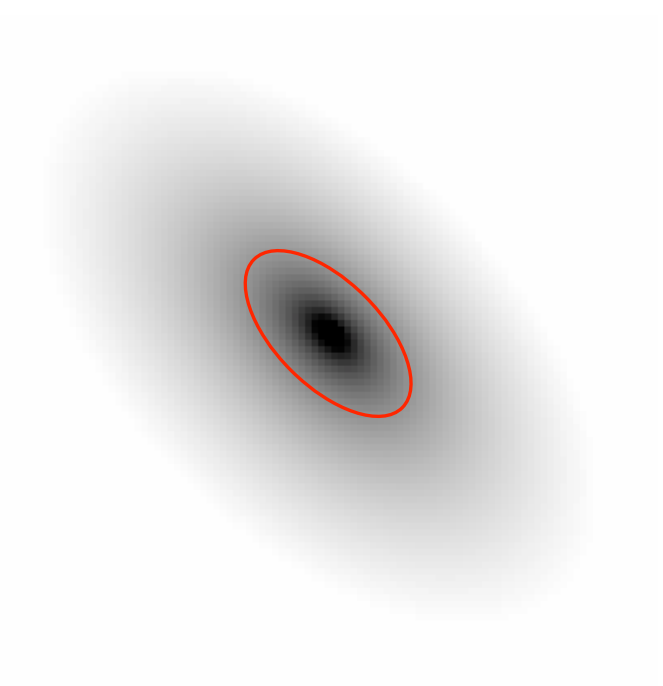


# New frontier: Detect zodiacal disks

- Search for scattered visible light from disks down to ~10x the zodiacal dust content of the solar system
  - ➢ Zodiacal disks come for “free” with planet search data
- Search down to the habitable zones (~1-2 AU) of stars within 10 pc
- Amount of dust measures interactions between rocky bodies:
  - ➢ *Important to assess for future Earth-like planet imaging missions*
- Visible & unseen planets sculpt the dust dynamically
- WFIRST-AFTA visible + LBT-I mid-IR → grain albedo + area
- Only massive (~1000 * solar) debris disks have been resolved in scattered light so far: *WFIRST is >100x better!*

# What do Zodiacal disks look like?

Zodiacal light seen from Paranal



- Zodipic (Kuchner+ 2001, 2007) model of solar system zodical disk at10 pc at $\lambda$ = 550 nm
- Zodiacal light surface brightness goes ~ $r^{-2.2}$
- Red ellipse shows r ~ 2AU region (~200 mas with14 mas / pixel)

Log Flux scale from 1E-11 - 1E-8 Jy

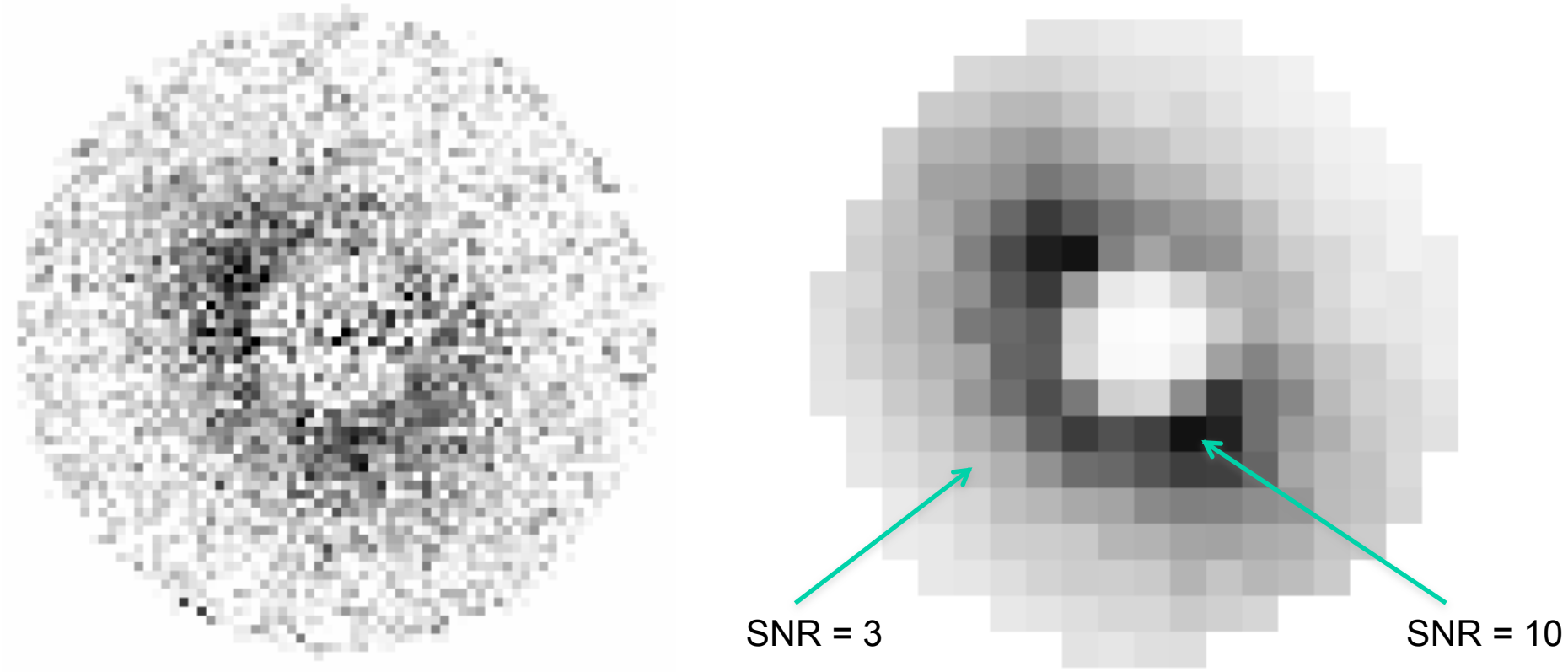
(Sun would be V = 41 Jy at d = 10 pc)

# WFIRST Zodiacal Disk Image Simulations

*Simulate AFTA Coronagraph disk images to explore science potential*

- Take advantage of the detailed coronagraph modeling work done at JPL
- WFIRST + coronagraph simulation results provided by John Krist (JPL):
  - PSF, occulting mask transmission, dark hole speckle field
  - Have done simulations for Hybrid Lyot and Shaped Pupil coronagraphs
- Simulate WFIRST zodiacal disk images:
  - Create model disk images with M. Kuchner et al. Zodipic 2.1
  - Convolve model with WFIRST coronagraph PSF
  - Multiply by occulting mask, photon conversion efficiency, field stop
  - Add photon noise and speckle noise = 0.1 x dark hole speckle field

# Resolved 10 zodi disks detected at modest SNR

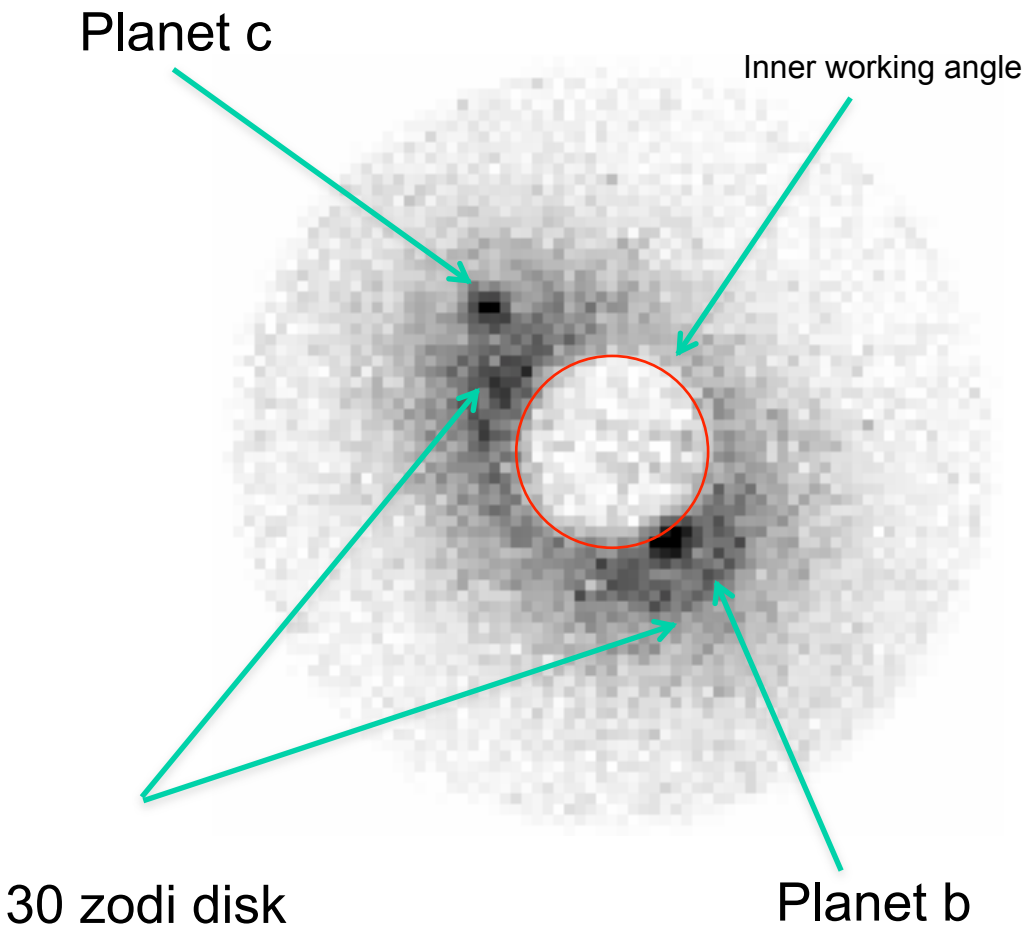



- Left: Simulated 24 hr WFIRST-AFTA-HLC image of 10 zodi disk around GV star at d=14 pc. Scale is 0.014 arcsec / pixel and 0 – 20 electrons
- Right: SNR of image at left, binned into 1.2 λ/D (4 x 4 pixels) resolution elements

# WFIRST Simulated Image of 47 UMa System

*Add planets to zodipic disk model images using planet phase / illumination relations (e.g., Charbonneau et al. 1999)*

- 47 UMa System with known RV planets (~Jupiter masses)
- G1V star at 14 pc
- Planet b has SMA = 2.1 AU, planet c has SMA = 3.6 AU
- Assume 30 zodi dust dust (628 zodi measured 3 sigma upper limit, Millan-Gabet et al. 2011)
- Assume incl 60 d, PA 45 d, pl. albedo 0.4, pl. orbit -90 d & 70 d




Simulation of a 10 hour exposure with HL coronagraph (0.4 mas jitter / 10x speckle suppression, 550 nm 10% BW)

***- Gravitational dynamics are NOT included!***

# Value of disks + planets together

- Planets without zodiacal disks indicate little recent collisional activity, like our solar system
- Disks without planets indicate significant interaction of small bodies only, no large ones “made it”
- Disks and planets together will reveal the dynamics of their interactions via disk gaps & non-uniformities
- Neither disks nor planets indicate efficient clearing of the pre-planetary disk